

**JOURNAL OF THE**  
**BOSTON SOCIETY**  
**OF**  
**CIVIL ENGINEERS**

**OCTOBER, 1929**

**Featuring**

**Pier Construction for the  
Mid-Hudson Bridge at  
Poughkeepsie, N. Y.**



**Vol. XVI**

**No. 8**

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715 Tremont Temple, Boston

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Published Monthly, except July and August, by the Society  
715 Tremont Temple, Boston, Massachusetts

Subscription Price, \$4.00 a Year (10 Copies)  
50 Cents a Copy

Copyright, 1929, by the Boston Society of Civil Engineers.  
Entered as second-class matter, January 15, 1914, at the Post Office  
at Boston, Mass., under Act of August 24, 1912.

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Acceptance for mailing at special rate of postage provided for in  
Section 1103, Act of October 3, 1917, authorized on July 16, 1918.

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BOSTON  
WRIGHT & POTTER PRINTING COMPANY  
32 DERNE STREET

# JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

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## PIER CONSTRUCTION FOR THE MID-HUDSON BRIDGE AT POUGHKEEPSIE, NEW YORK

BY JAMES W. ROLLINS \*

(Presented at a meeting of the Boston Society of Civil Engineers, May 15, 1929)

UP to 1924 no highway bridge spanned the Hudson River between Albany and the Atlantic Ocean. In that year a highway suspension bridge was built at Bear Mountain, forty-three miles above New York City. In 1923 a movement was started for the construction of a bridge at Poughkeepsie, a site considered most favorable, with high bluffs on both sides of the river, which at that point is 3,000 feet wide. On June 2, 1923, the New York Legislature passed an act authorizing the construction of a suspension bridge at Poughkeepsie, under the Department of Public Works of the State of New York. The plan provided for a center span of 1,500 feet, two shore spans of 750 feet, with a clearance above the river of 135 feet, supported by two piers in the river.

### AWARD OF CONTRACT

The work of construction for the two river piers was advertised, and the bids for this work, received in March, 1926, were as follows:

|                                                |             |
|------------------------------------------------|-------------|
| Phillipsburgh Construction Company . . . . .   | \$1,841,545 |
| Trieste Construction Company . . . . .         | 1,916,440   |
| Missouri Valley Construction Company . . . . . | 2,108,817   |
| Engineers' estimate . . . . .                  | 2,145,545   |

\* Vice-President of the Blakeslee Rollins Corporation, Boston.

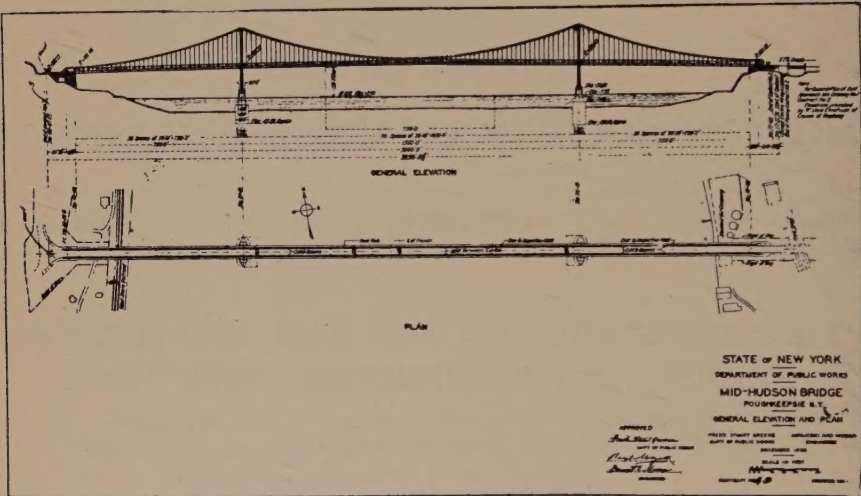


FIG. 1. — ELEVATION AND PLAN OF MID-HUDSON BRIDGE

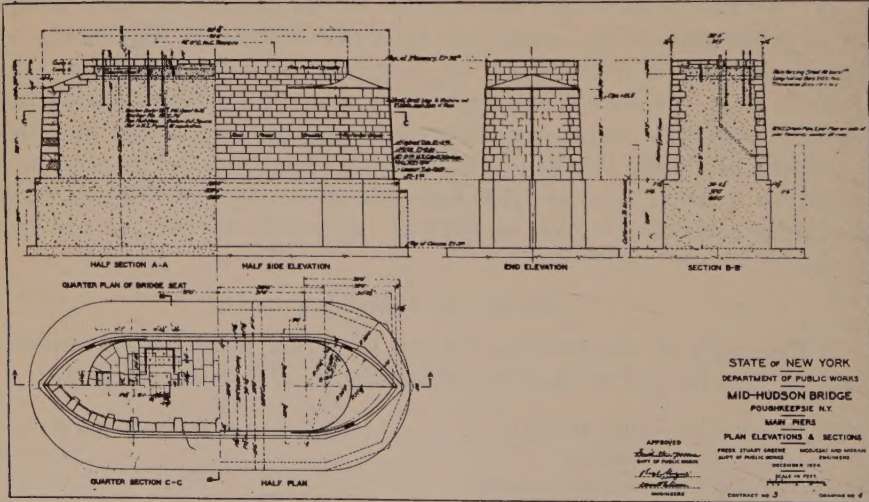


FIG. 2. — MAIN PIERS

The low bidder, in the opinion of the State engineers, had not had the experience necessary to qualify him to do this work, and he was given permission to withdraw his bid; but he insisted, and the contract was awarded to him. However, he could not furnish the necessary bond, so the work was re-advertised.

New bids were received in May, 1926, as follows:

|                                                                  |             |
|------------------------------------------------------------------|-------------|
| Blakeslee Rollins Corporation of Boston . . . . .                | \$1,889,000 |
| Arundel Corporation of Baltimore . . . . .                       | 1,895,000   |
| Trieste Construction Company . . . . .                           | 1,979,000   |
| Missouri Valley Construction Company, Leavenworth, Kans. . . . . | 2,025,900   |

The contract was awarded to Blakeslee Rollins Corporation and signed May 19, 1926.

It will be noted that four of the bids received ranged between \$1,841,000 and \$1,916,000, indicating very close figuring for this very difficult work.

#### GENERAL DESCRIPTION

This contract provided for the construction of two piers in the Hudson River, each 60 feet in width by 130 feet in length, with semi-circular ends having radii of 30 feet, by the open caisson method, dredging through 25 open pockets with clamshell buckets. The outside walls of the caissons were  $3\frac{1}{2}$  feet thick; the two inside longitudinal and the end brace walls were 3 feet thick; the cross walls were  $2\frac{1}{2}$  feet thick. All the walls of concrete were heavily reinforced, requiring 700 tons of steel.

The foundation of the easterly caisson was to be on hard pan, 135 feet below the water level, and of the westerly caisson to 115 feet below the water level.

#### DESIGN OF CAISSONS

The design of these caissons was unusual, and, as far as the writer knows, has never before been used in caissons of this size. There were no air pockets, so called, but the caisson consisted merely of an outside shell, with cross and longitudinal walls, making 25 pockets of full size from top to bottom of the caisson. This design called for false bottoms in all pockets, strong enough to withstand the pressure of 80 feet of water, the depth to which the engineers thought the caissons would probably be sunk before the bottoms were removed.

The bottom section of the caissons was a steel structure 21 feet high, with heavy girders and braces, and a one-half-inch steel shell on the

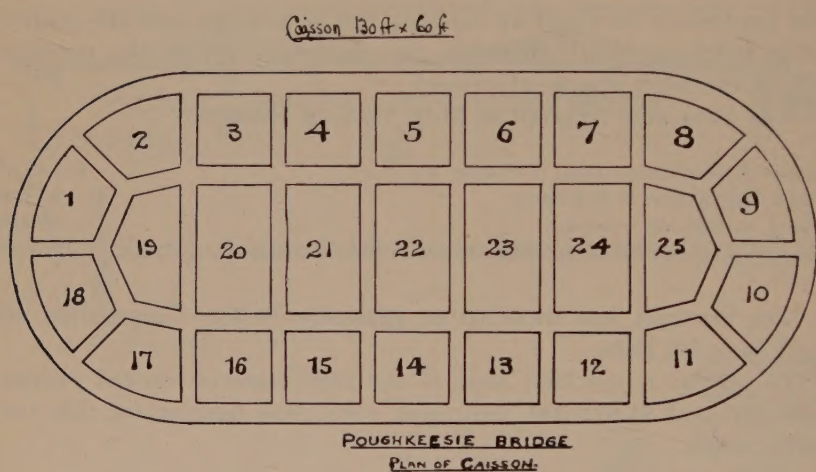


FIG. 3. — PLAN OF CAISSON, SHOWING POCKETS

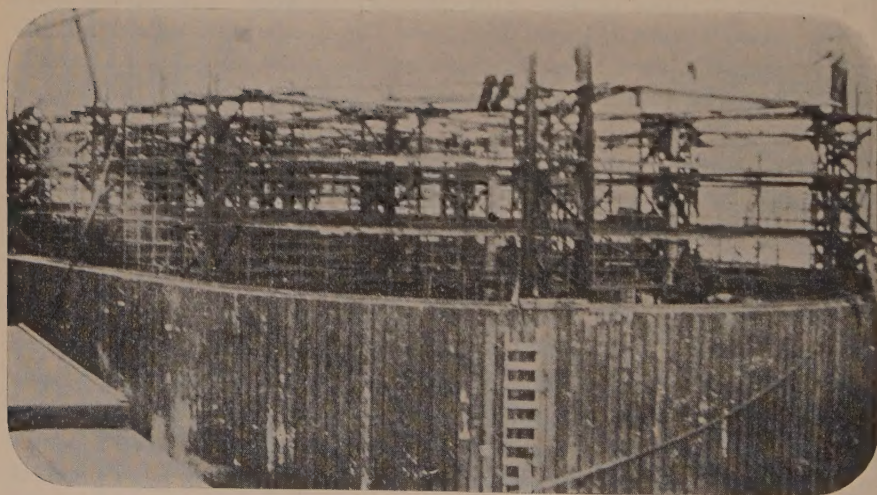


FIG. 4. — SIDES OF CAISSON AND STEEL FALSEWORK

outside. Structural steel columns consisting of four vertical angles, latticed, were carried up from the steel cutting edge section at all intersections, and on these columns 3" x 4" horizontal angles were bolted on each side of all walls, to carry the outside shell, which was of plank 4 inches thick, and also the concrete forms for the interior walls. Above

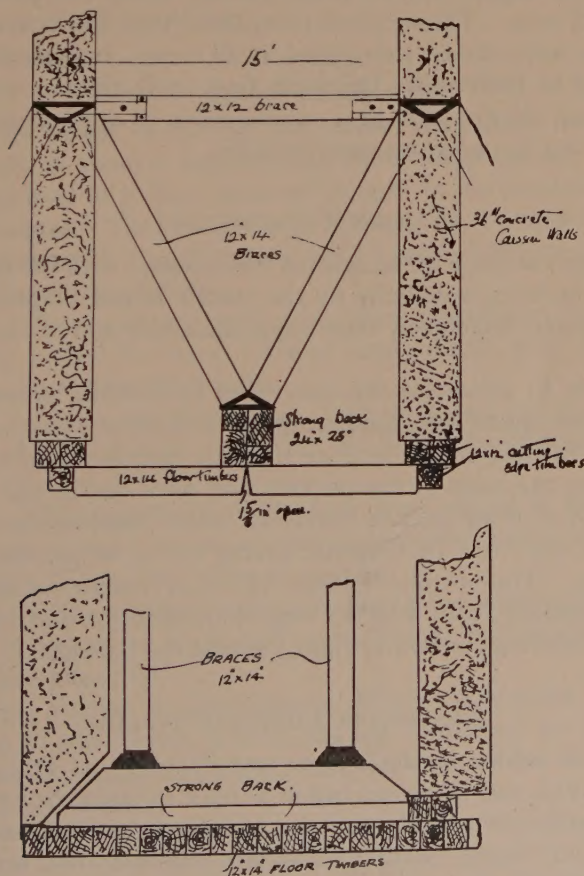


FIG. 5. — BRACING FOR FALSE BOTTOMS

the steel cutting edge section the walls were carried up in 16-foot sections, the interior columns of structural steel being built in 32-foot sections.

A provision of the specifications was as follows: "The caissons have been so designed that by the addition of suitable water-tight diaphragms, or false bottoms, to be removed after the caisson has been landed, placed

at the cutting edge level, and by keeping the areas above the false bottoms continuously de-watered, the weight of the steel framing and concrete walls below any horizontal plane will be less than the displaced water to the same level."

The weight of the concrete walls, per each vertical foot, was about 204 tons (the weight of 102 cubic yards), while the water displaced weighed 228 tons. These calculations show that the concrete walls of the caissons were almost submerged at all times, and required that the outside shell be built above the water line. Calculations as to stability of the caisson showed that at a submergence of approximately 50 feet the caisson was in a great measure *unstable*.

### CAISSON CONSTRUCTION

The steel cutting edge sections of the caissons, with the false bottoms and braces built in, were built by the Staten Island Shipbuilding Company, at Staten Island, on ship ways, launched and towed to Poughkeepsie.

In order to withstand this enormous hydrostatic pressure of 5,000 pounds to the square foot, the bottoms were built of 14-inch solid timber for the east caisson, and 12-inch for the west caisson. These timbers had a bearing on the sides of the pockets and were cut in the middle, but supported by a strong-back of timber 24" x 28", holding the centers; the strong-back was held by diagonal braces 12" x 14" in the top of the steel caisson. The bottom timbers, 12" x 14", were caulked with dry white pine wedges about 4 inches long, 4 inches deep, and  $\frac{1}{2}$  inch at the butt end, providing very water-tight joints in the bottoms.

### PLACING OF CONCRETE WALLS

The first section of the caisson was delivered at Poughkeepsie on March 26, 1927, and work was begun at once to build the concrete walls.

The specifications of the contract provided that concrete should not be placed by a "chute," so that a standard concrete tower was built, with a vertical hoist bucket, for depositing the concrete on a horizontal belt, which was carried on a steel frame extending out over the caisson, the belt delivering concrete into a hopper, which discharged it through a short pipe into the walls. This combination proved to be a failure, because the steel frame, 50 feet long, carrying the belt, was not steady, under the varying weight of the concrete and the swaying of the mixer scow; consequently, the belt would not stay on the carriers, and the delivery of the concrete from the belt was spasmodic. We played with this

arrangement for thirty days, our best day's work being 200 yards of concrete, not enough for our daily requirements.

We therefore asked the engineers to change the specifications and allow us to spout the concrete from the tower in the usual way; and this change was made. The sides of the caisson above the steel cutting edge section were in 16-foot sections, so that at times we had to spout the concrete vertically about 40 feet.

### SEQUENCE IN BUILDING SECTIONS

When the weight of the concrete caused the caisson to settle down to a freeboard of about 6 feet, another set of sides was put on. These were built on land in 16-foot sections, brought to the caissons and bolted to the side angles. The procedure in building up the sides after the deposited concrete had caused the caisson to settle down to a free-board of about 6 feet was as follows:

*First.* — The structural steel posts were placed and the angle-iron longitudinals bolted to them. These longitudinals were 4 feet apart vertically on both sides of all walls.

*Second.* — The outside shell was built of 4-inch pine in sections 15 feet long and 16 feet high, bolted to the 4-inch horizontal angles, and caulked.

*Third.* — The reinforcing rods were then placed in the walls, the horizontal rods being 2 feet on centers on both sides of the walls, and the vertical rods, on both sides, 4 feet on centers.

*Fourth.* — The wooden concrete forms on the inside walls were then placed and bolted to the horizontal angles, having been made up on shore in proper panel lengths.

The total number of operations necessary to complete these 16-foot sections was 24,000, including bolts and wire fastenings for the reinforcement. These sections were completed in five days, with some night work, using a force of 150 men.

### SOURCE OF MATERIAL

The concrete material was delivered on scows: the cement in 1,000 barrel lots was received from the Atlas Portland Cement Company's plant at Hudson, forty miles up the river; the crushed stone came on 600-yard scows from the New York Trap Rock Company's plant, eight miles below the bridge site; and the sand, on 700-yard scows, from the Seaboard Sand and Gravel Company at Long Island.

## MIXING PLANT

The concrete mixing plant was built on half of a big carfloat, 120 feet long, 40 feet wide, and 12 feet deep.

The sand and gravel were taken from the scows with a  $1\frac{1}{2}$  yard Williams clamshell bucket, using a heavy A-frame and 90-foot boom rig, operated by a 10" x 12" 3-drum Lambert hoisting engine. This material was dumped into hoppers 30 feet above the deck of the scow, fed into measuring hoppers and with the cement into the mixers, consisting

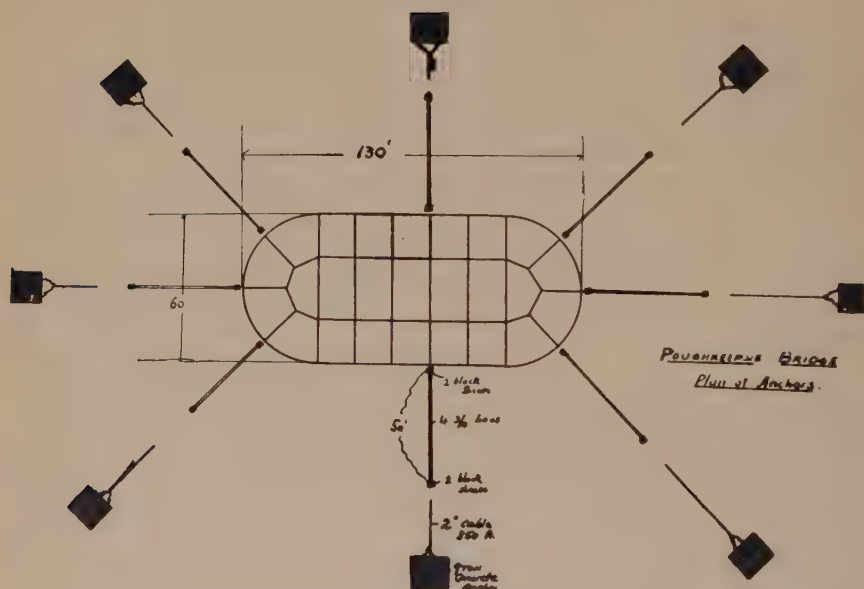


FIG. 6. — ANCHORS FOR CAISSON

of two 1-yard Rex mixers, driven by electric motors, and then dumped into a 1-yard bucket in the tower hoist.

The cement was unloaded from the covered scows to a movable horizontal belt, operated by a motor on a steel frame, which projected into the deck-house on the cement scow, and then carried and dumped upon a horizontal belt which carried it up to the mixer location, and by another inclined belt up to the mixing platform, thence into the mixers.

The concrete was 1-2 $\frac{1}{2}$ -5 mixture for nearly all the work.

## ANCHORAGE OF CAISSONS

Concreting of the walls was done at the dock until the caisson had a draft of 13 feet, and it was then towed out to the site of the east pier, on the Poughkeepsie side of the river. The caisson was held in position by eight concrete anchors, each weighing 30 tons. Two anchors were placed on the ends of the caisson, two on the sides, and four on the four corners. These anchors were placed about 350 feet from the caisson and connected to it by 2-inch plow steel cables, having an ultimate strength of 166 tons. These cables ran to a point about 50 feet from the caisson, and were there fastened to a four-sheave purchase, which was fastened to links of 3-inch iron in the caisson structure, the free ends of the purchases being carried up to the top of the caisson and there fastened to the timbers. With these eight hitches there was no difficulty in holding the caisson in position.

## SINKING OF CAISSONS

The rise of the tide at Poughkeepsie is about 5 feet, maximum, and the rate of the flow of the tide is about 1.2 miles per hour. The river at this point was 57 feet deep. A study of the borings indicated that the top was very soft material, and therefore the engineers believed that we could sink the caisson to -80 feet by means of the weight of concrete in the walls, *without taking out the bottoms*, and also that the tide would scour out many feet of the mud underlying the caisson.

When the caisson was sunk to about -55 feet, we were instructed by the engineers to put 200 yards, more or less, of sand in the bottom of the caisson, to secure stability. This was done, but it was very difficult later to get this sand out from between the braces and other timbers, before we could remove the false bottoms.

At this stage of the work we had trouble in keeping our scows from breaking down the sides of the caisson, which consisted only of 4-inch vertical pine plank, bolted to the 3" x 4" horizontal angles, 4 feet on centers, which in turn were bolted to the structural posts, 15 feet on centers. The concreting plant consisted of the heavy mixer scow, a scow of gravel and one of sand, alongside, a cement scow on the end; and this combination of floating equipment was held off from the caisson sides by a 2-foot rolling fender, which was not sufficient to keep the sides from bending. To protect the caisson from the action of this floating plant the outside concrete walls,  $3\frac{1}{2}$  feet thick, were built up

about 4 feet above the water line, and always maintained at that relative height. This necessitated bulkheading the outside walls and a length of each cross wall adjoining.

### EAST CAISSON

The east caisson was towed out into the river and anchored on the site April 20, and work was then begun on building up the walls, thereby sinking the caisson. This work was continued until the caisson landed on the bottom of the river, June 7, at elevation  $-56.5$ , and the anchor lines attached. The concreting of the walls was continued until the caisson was sunk to elevation  $-64$ , that is,  $7\frac{1}{2}$  feet into the material at bottom of the river. This was done on June 30.

The walls at this time were 68 feet high, and the caisson weighed about 15,000 tons, which, distributed over the total area of the caisson, namely, 7,364 square feet, created a load of about 2.1 tons per square foot.

As the caisson showed no inclination to settle further, we prepared to remove the false bottoms, which were made up of a solid floor of 14-inch thick timber, as described above.

### REMOVAL OF FALSE BOTTOM

The theory of removal of these false bottoms was that by removing the diagonal braces the bottoms would collapse under the hydrostatic pressure of 65 feet, and the floor timbers float upwards.

Our first attempt to remove the braces was to try to pull the tops out from the castings with wire ropes fastened to 1-inch eyebolts which had been placed in the top ends of the braces for this purpose. We could not start the braces by this method. We then sent for an expert dynamite man, and, under his direction, placed a stick of dynamite in a hole in the braces. We blew this, but obtained no results other than the making of a larger hole in the brace. We then put a girdle of dynamite sticks around the braces, and blew that charge, with no practical results. Our next attempt was to put six sticks of dynamite in the fork at the casting at the foot of the braces. This broke the braces loose and we fished them out with buckets, although they often got fouled in the pockets.

To our sorrow, when the braces were blown out and removed, nothing more came up, not even the strong-backs, which were not (as far as we knew) bolted to anything. With our heavy buckets we actually gnawed these timbers out, breaking or bending every bucket we

had. These strong-backs, 24" x 28" in section and about 10 feet long, were very awkward pieces to get out, even when free. We had expected that when the braces and strong-backs were out, the bottom timbers would come up, but again we missed our guess, and not one came up.

We dug a trench outside the caisson on the northeast end, 60 feet long, to get a water pressure of 65 feet against these timbers, with no results. After days of work, dropping an 8-ton concrete pile on the bottom, battering it with a heavy timber with a steel cutting edge, in a pile-driver leads, and clawing away at the timbers with our heavy buckets, we managed to get them out one by one. We finally got out the timbers of pockets Nos. 3, 5 and 7 on the easterly side; Nos. 20, 21, 22, 23 and 24, the center straight pockets; Nos. 15 and 16 on the west side, with No. 12 partially out. Even with some of the timbers out of a pocket, the balance would stick, and we had to fish with our buckets for them.

With the removal of these 12 pockets, about  $\frac{3}{10}$  of the area of the caisson was unsupported, but it sank only about 2 feet, to elevation -67, which was only about 10 feet into the bottom.

This work had taken three weeks of intensive work, day and night, and we were much disturbed and discouraged at the slow progress.

The writer expressed the opinion at this time of the possibility that the caisson was resting on a sort of "india rubber" stratum, as shown by the material excavated from the pockets, and that the caisson might break through at any time. But the caisson was stuck, and there was a freeboard of only 6 feet. Consequently, for protection against danger due to further settlement, and to get additional weight, the concrete walls were built up for another section of 16 feet. The work on the removal of the false bottoms was continued as well as the dredging in the open pockets, but with no appreciable results, although the caisson had a list to the west of 2 feet.

### SUDDEN SINKING OF CAISSON

The excavation had been carried a little deeper in pockets Nos. 3, 5 and 7, on the easterly side, because the caisson at that time had a 2-foot list to the west. Very suddenly, early in the morning of July 26, the bottom on the east side broke and the caisson sank 30 feet, approximately, and tilted to an angle of 43 degrees to the east, the low corner being down to -96, and only about 7 feet of the high corner remaining above the water level.



FIG. 7. — EAST CAISSON JUST PRIOR TO ITS TIPPING

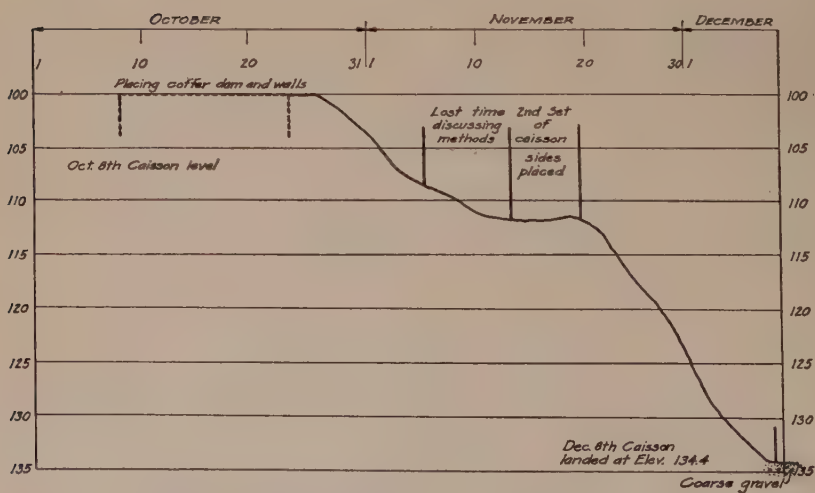


FIG. 8. — PROFILE SHOWING SETTLEMENT OF EAST CAISSON, OCTOBER, NOVEMBER AND DECEMBER, 1928.

While there were some doubts as to the stability of the caisson when it was drawing 50 to 55 feet, after it was landed for a finality on the bottom, and 10 feet into it, its stability under that condition had not been questioned, and, in fact, the caisson had been rocked back and forth by excavating in the pockets, in the efforts to sink it.

The east side pockets Nos. 3, 5 and 7, having a total area of about 450 square feet, were partially balanced on the west by pockets Nos. 15 and 16, with an area of 300 square feet; the five center pockets, of 1,320 square feet, total area, being in the center, were theoretically neutral. The total area of the caisson was 7,346 square feet, so that only



FIG. 9. — EAST CAISSON, JULY 27 — DAY OF TIPPING

30 per cent of the area was without a bearing, and the caisson had been resting on this area for twenty-six days with a settlement of only 2 feet.

Apparently a break in the supporting stratum on the east gave way, and although the list of the caisson was 2 feet to the west, after that list was overcome, the superimposed load, above the water, *i.e.*, the weight of 20 feet of concrete (2,000 yards=4,000 tons), made the overturning more rapid and extensive.

The writer, all in ignorance of this calamity and of the "pleasant" news awaiting him, arrived in Poughkeepsie at 10 A.M., and was met by one of the engineers, who told him the sad tale.

## THE PROBLEM OF RIGHTING THE CAISSON

The situation, then, was this: The caisson, weighing 12,000 tons submerged, resting on a soft bottom 96 feet below the water level, with no solid support for 40 feet more, was tilted to an angle of 43 degrees, with only 7 feet of the high corner visible. Our first thought was to get a pull on the high side and dig out under the bottom in an effort to pull the caisson over. For this purpose a 2-inch steel cable was ordered from New York, and sent under special police control.

Then we had a council of war — representatives of the State, the Superintendent of Public Works, the engineering force and the contractors — and went over the whole proposition. The first step agreed upon was the application of a force to stop further rotation of the caisson. This was to be accomplished by the use of lighters to produce a lift of 50 tons on the low side, and also by using pontoons from New York with a lift of 300 tons additional.

The caisson went over so quickly, the whole movement occurring within about thirty seconds, that it brought up hard on the east side, and after that it showed no indication of further movement.

The next step considered at this conference was the question of dredging under the caisson and exerting a pull to the west to straighten it up, but the engineers would not approve this action, claiming that the support under the caisson might give way and the caisson slide down to a horizontal position.

The alternative proposition made by them was the building of an airtight roof on pockets Nos. 3, 20, 7 and 4, and the pumping of air into these pockets to create a lifting force of 600 tons. Plans were made for this scheme, material bought, including 20 tons of heavy I-beams, and most of the framework completed on land, when this plan was abandoned, after four weeks of time and labor.

The next proposition was to build a cofferdam up on the sides, and pump the water out of some of the *whole* pockets, 15 in all, which still retained the bottom timbers. Four weeks were spent on this plan, but finally it was deemed impracticable and abandoned.

Meanwhile, in an effort to shift the center of gravity, three cribs were built, loaded with 80 tons each, and lowered down on the west side of the caisson, suspending them from the exposed top of the concrete walls. Also the west side pockets, Nos. 12, 13 and 14, were filled with about 25 feet of mud.

The next experiment was ramming vertically with a long timber,

16" x 16", against the east side, and crowding gravel into the spaces in an attempt to wedge the caisson over.

The engineers, meanwhile, adhered to their objection to doing any dredging under the caisson.

After almost three months of experimenting and accomplishing nothing, the engineers turned the troublesome problem over to the contractors.

#### CONTRACTOR'S PLAN FOR RIGHTING CAISSON

We offered the following plan: To sink out in the river six cribs weighing 1,200 tons, attaching 2-inch steel cables to them, and leading



FIG. 10. — CABLES FOR RIGHTING CAISSON

these cables over a carfloat 240' x 40' x 12', and attaching to them a 4-ply luff tackle, which was fastened to the crib. The free end of this luff was led to a framework (gallows frame) on the west side of the float, passed over a block in the top of the A-frame, and on the end of the rope a 6-ton block of concrete was hung. This weight, minus the friction, created a pull of about 75 tons on the caisson, and as we had 12 of these lines, a total of 900 tons' pull was exerted on the top of the caisson. We also put a double set of booms, six being 70 feet long with a 50-ton weight on each, and four 90 feet long with a 10-ton weight on each, on the west side of the caisson. The combined pull was then about 1,500 tons.

As the caisson weighed 12,000 tons and was off center of gravity 3 feet, there was a moment to further overturn of 36,000 foot-tons. Our 1,500-ton pull, however, had a moment arm of about 100 feet, so our righting moment was 150,000 foot-tons.

While doing the work of rigging up these pulling forces, we worked continually on excavating under the caisson, by digging through the center pockets which had no bottom, down the 43 degrees angle, and also a trench outside the caisson on the west side, and by jets worked by divers, jetting the material in these pockets out into the trench on the westerly side, where the clamshell buckets could get it. There was no particular trouble in cleaning out this material (a silty clay which would not run but would stand up vertically). In the middle section of the caisson, pockets Nos. 20 to 24 were open, but the bottoms still remained in Nos. 25, 9, 10 and 11, on the south end, and Nos. 19, 1, 17 and 18, on the north end.

It became apparent that to move the caisson it would be necessary to undermine the ends of the caisson, four pockets at each end. To do this excavation in the way we had been doing would require the jetting of a large quantity of material, for a long distance, into the trenches dug outside the ends of the caisson. A proposition was made that this excavation be done with a drag-line scraper. We had no great faith in this, as we thought we should be unable to control the scraper, but knowing the difficulties of the jetting and dredging plan, we were willing to try anything. So we bought a special drag-line bucket with teeth on both sides, sunk a concrete anchor in pocket No. 24 with a block on it, ran a line to which we attached this drag-line bucket, from a lighter at the caisson, through this block out under the caisson to another lighter anchored 200 feet from the caisson, and with these two lighters dragged this bucket back and forth under the caisson, dumping the contents of the bucket in a deep trench dug outside the caisson.

By using all the above methods, the material under the westerly portion of the caisson to the easterly longitudinal wall, about  $\frac{3}{4}$  of the width of the caisson, was excavated to about elevation -85.

It was the general opinion of all connected with the work that no rotation could be effected until the caisson settled and broke the friction against the east bank, where it had been resting for six months with no settlement. The caisson, however, did not settle, but on May 13 a rotation of 5 inches was reported, with no settlement, and thereafter the rotation was gradual, never exceeding 2 feet in 24 hours, until it was finally righted on August 7.

The easterly cutting edge had gone down to elevation -96. The

sides of the caisson, however, had been built only 85 feet high, so that, if the caisson were to be righted, revolving on the easterly cutting edge, the top would be 11 feet below the water level, which would require the last set of caisson sides to be put on in 11 feet of water.

The west side of the caisson in the inclined position was about 7 feet above water, and as soon as the caisson began to rotate, the last set of sides were added to that part, and as the rotation continued, the building up of the sides continued, also, finishing the east side under water. To help rotation the concrete was added to the west walls, until the concrete reached a height of 105 feet, which was the top of the walls and the connection of the cofferdam section. The placing of the outside sheeting, the structural steel, the reinforcing, the concrete forms and the concrete for the walls of the easterly half of the caisson had to be done under water, making the connections with divers.

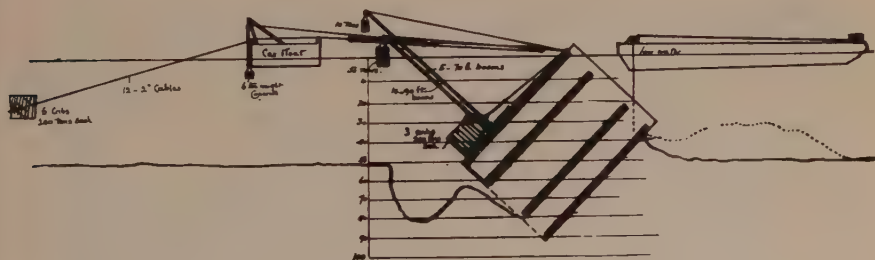


FIG. 11. — SKETCH OF RIGHTING FORCES

Before the caisson rotated, the whole of the structure was carried on the easterly side wall, the easterly longitudinal wall, and the cross walls between them, an area of 1,500 square feet, supporting the 12,000 tons of caisson, less that part of the weight carried on the bank on which it rested. As the caisson rotated, the other walls afforded some bearing. During the rotating period the additional weight of the top section of concrete walls, weighing 4,000 tons, did not cause the caisson to settle, and when finally leveled up it was higher than when we started the righting forces, apparently rotating about a point 10 feet inside the easterly wall.

We all were fearful of a sudden rotation of the caisson, judging from the original movement, so that we attached two preventor cables on the east side wall for safety, but there never was any inclination of the caisson to get a westerly list.

After the caisson had been righted, at elevation  $-96$ , and the concrete walls finished, we put up our first set of cofferdam sides, luckily being able to make the connection with the walls above the water.

The remainder of the false bottoms were then blown out without much delay, we having learned by experience how to do this. The dredging was continued, sinking the caisson through coarse sand, which offered little frictional resistance, to elevation  $-134.5$ , a depth which afforded a thick stratum of coarse sand and small boulders.

#### THE SATISFACTION OF SUCCESS

Thus ended a proposition which at first seemed hopeless, with no precedents as a guide, involving enormous weights to be handled under

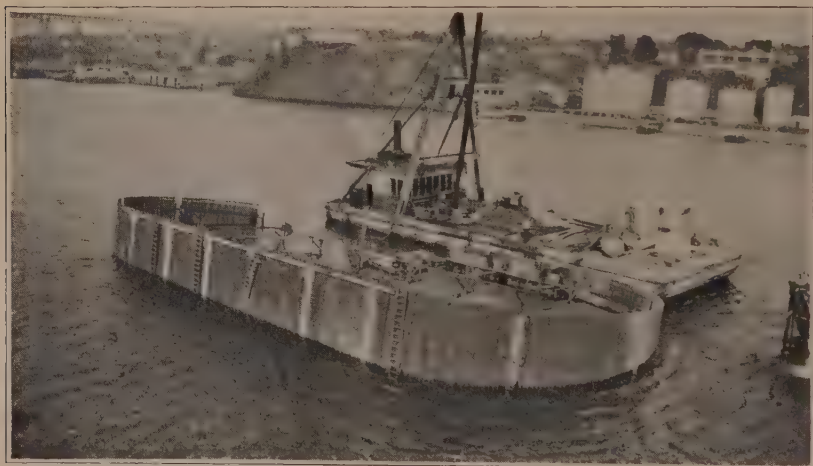


FIG. 12. — EAST CAISSON NEARLY RIGHTED, AUGUST 2, 1929

most adverse conditions. The thought of the other result — failure — was appalling, for the wrecked caisson would have been on the site of the pier and could not have been blown apart without throwing the parts of steel and concrete over a new site alongside; or else the almost impossible proposition of sinking a new caisson by air to *go through the old wreck*; or a third alternative, probably the best one, of changing the location of the new pier to go outside of the wreck.

The one pleasing recollection in this most difficult and trying work was the optimistic support of the Superintendent of Public Works, Col. Frederick Stuart Greene, and his chief engineer, Col. William M. Ache-

son; of Messrs. Modjeski & Moran, the engineers, and their assistants, Messrs. Hanson and Angier. We all felt that we must right that caisson, and we did it.

### THE WEST CAISSON

The west caisson was delivered at Poughkeepsie on April 23, with the false bottom and braces in place. The caisson when launched had a draft of only 4 feet, and was remarkably water-tight.

At the dock, concrete walls were poured until the caisson was drawing  $14\frac{1}{2}$  feet, then it was towed to its position on May 26, and anchor hitches made. Concreting was then continued until the caisson was landed on the bed of the river at elevation -57, on July 3.



FIG. 13. — PLANT IN RIVER FINISHING EAST PIER

As very great difficulty had been experienced in removing bottoms from the east caisson, it was thought wise to make preparations to remove the bottoms of certain pockets from the west caisson, which was now resting on the bottom with a draft of about 65 feet and was switching about with the tides in a rather dangerous way.

### SINKING OF WEST CAISSON

On July 12 concreting operations were being conducted on this pier, and the caisson was settling slowly under the added weight, yet, having a freeboard of concrete of about five or six feet. In view of the extreme

difficulty of removing the braces which held the bottoms in place, it was thought wise to remove some of these braces in this caisson so that the bottoms could be more quickly removed when the time came for it. A diver was sent down and the braces in pockets Nos. 3, 7, 12 and 16 were loaded with dynamite, ready to be removed. The caisson at this time was less than a foot out of position, with reference to both center line of pier and center line of bridge. Late in the afternoon of the 12th the dynamite charges in pocket No. 12 were exploded, and the caisson immediately took a perceptible list to the southwest, *i.e.*, toward the corner where pocket No. 12 was located. The diver made a hurried examination and reported mud and timbers to a height of 40 feet above the cutting edge in pocket No. 12. The caisson at this time had developed a list of about 2 feet to the southwest, and in order to correct this list the dynamite

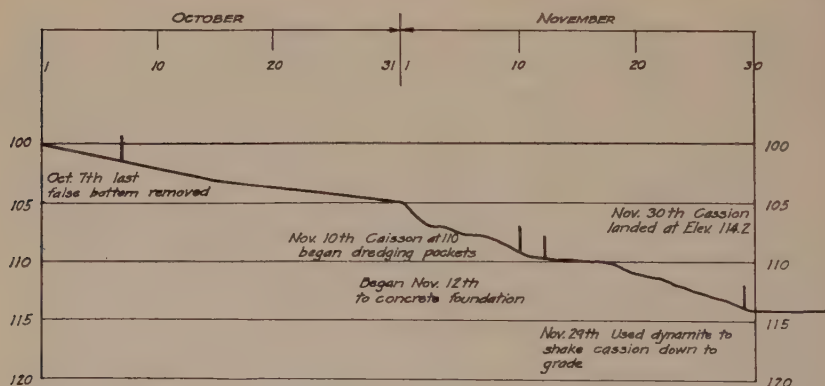


FIG. 14. — PROFILE SHOWING SETTLEMENT OF WEST CAISSON, OCTOBER, NOVEMBER AND DECEMBER, 1928

charges in pocket No. 7, southeast corner, were immediately exploded, an operation which leveled the caisson east and west, but it caused a list of 4 feet toward the south end. The area of these two pockets was only 300 square feet, while the area of the caisson was 7,600 square feet.

This rapid sinking was very alarming, because nothing of the sort had been experienced with the east pier, and, in fact, was not looked for on the west pier, inasmuch as the idea had merely been to remove the braces and not to disturb the bottom bearing.

It was evident, however, that the hydrostatic pressure had caused the upheaval of the false bottoms as though the caisson were still in the water. It was then decided to level the caisson; consequently, pocket No. 3, on the northeast corner, was shot. This pocket opened similarly to

pockets Nos. 7 and 12, with a corresponding decrease in the southerly list and an increase in the easterly list. The firing of pocket No. 3 was accompanied by considerable commotion and a jarring of the caisson structure.

### INCLINED AND LATERAL MOVEMENT

The caisson now had a list of over  $2\frac{1}{2}$ -feet to the east and about  $1\frac{1}{2}$  feet to the south. The obvious thing to do was to remove the other quarter pocket, on the northwest corner, in order to level the caisson. The dynamite charges failed to act, and it was necessary to reload them, and a diver was sent for, as this work was going on at about 10 P.M., and about 11 P.M. the braces were shot and the caisson leveled up.

During the operation of removing these braces and bottoms the caisson had settled more than 7 feet, and, upon checking up the position the next morning, the engineers reported that it had moved bodily nearly 7 feet to the west. Also this settlement reduced the concrete freeboard down to -1 foot at high water, and caused considerable seepage of water through the 4-inch timber sides of the caisson.

Concreting was therefore resumed immediately, and as much concrete as possible was poured in the next few days to develop the concrete freeboard, as the caisson itself was only partly flooded, and we did not know just how far it would sink, with an area of nearly 650 square feet of bearing gone. With the placing of this additional concrete and the resulting settlement, the caisson continued to move to the west until July 15, when a maximum movement of  $8\frac{1}{2}$  feet was recorded.

### REMEDY FOR LATERAL MOVEMENT

At a conference on July 15 plans were adopted for forcing the caisson back to its proper position. It was decided that a surcharge of 1,500 tons of crushed stone should be deposited against the west side of the caisson, causing a thrust towards the east. This was done immediately, and the effect was noticeable, as the caisson began to sink further by removal of additional bottoms. For the first 3 feet of sinking after the application of the surcharge, the caisson moved nearly the same distance to the east, and by September 15 half of the error to west had been corrected, and the bottom of the caisson had reached elevation -92.

The sinking of the caisson continued by the removal of bottoms and dredging, and the caisson moved fairly rapidly until it reached elevation -105, about November 1, at which time all of the false bottoms

had been removed and the error in position had been reduced to about 2 feet 6 inches.

The engineers were quite insistent on our maintaining a westerly list, due to the fact that hard material began to show up at about this grade, whereas the material under the east half was quite soft.

The operation of sinking at this time was seriously hampered by this insistence on a westerly list, and by the presence of big boulders, some of which ran as large as 2 cubic yards and were very difficult to remove from under the walls, and also difficult for our buckets to handle. Continuous jetting through 110 feet of 4-inch extra heavy pipes was carried on chiefly during daylight hours, and dredging was done at night. These jets succeeded in loosening boulders and softening up the clay so that dredging could be carried on below the cutting edges and allow the material to fall in. However, it was slow work at best, because the long jets were difficult to handle. They broke very easily when roughly handled, and were troublesome when passing steamers caused a wash.

Finally, charges of dynamite were resorted to for causing settlement of the caisson, and this brought it down to within 6 inches of contract grade.

#### FOUNDATION FOR CAISSON

The borings for this pier, ten in all, including six taken by the contractor in addition to the four of the contract, indicated a stratum of rock at elevation  $-117$ , located under the westerly edge of the caisson, while on the easterly edge, 60 feet distant, the hardpan (no rock) was down to  $-127$ . Various studies were made to get a good foundation for the whole area of the caisson, and finally the following plan was decided upon.

The caisson was down to elevation  $-114.5$ , and level, and within a foot of position all ways. Excavating was then carried on through one of the easterly side pockets, which was  $12\frac{1}{2}' \times 12\frac{1}{2}'$ , inside dimensions, with a large clamshell bucket, down to hardpan, about  $-125$ , through silt and sand and clay, which kept a remarkably vertical slope. Immediately, the hole so dredged was filled with concrete up to the cutting edge. Another pocket not adjoining the first was then dredged out and filled with concrete. This process continued, work being done on staggered pockets.

For the excavation in the immediately adjoining pockets we put down a powerful jet and washed out all the loose material, removed it by dredging, and filled the pockets with concrete up to the cutting edge.

## CONCRETE FILLING OF POCKETS

After the completion of the foundation work the pockets were filled with concrete to grade —31, the top of the underwater concrete, making this a continuous job, working a double shift, and putting in 600 to 800 yards of concrete in twenty-four hours, with a 2-yard submarine bucket. This work was finished before the river froze on December 25, 1927. The river work was thereafter abandoned until March 15, 1928.

Above grade —31 the work was done inside a removable cofferdam. We had remarkable luck with this structure, the top of which was at grade + 7, so that it took all the shock of the drifting ice during the winter. It stood the test, the only trouble being a hole broken through on the south end, above the low-water level, — a break which was easily repaired. Extra braces were placed for the winter, and the whole structure held so well that a 6-inch pump kept the water out during the balance of the work.

We were so pushed with the concrete work in 1927 that we did not have time to clear out the laitance in these pockets, which were built up from —117 to —31, 86 feet, in a continuous pouring. The result was that when the cofferdams were pumped out in the spring there were from 20 to 30 feet of mud, silt and laitance in the pockets, and the bottom part of the laitance was so hard that it was necessary to use jack-hammers to remove it. The balance of the work on the westerly pier was finished with no delays or trouble.

From our experience in sinking these caissons, it now is our opinion that the same trouble would have occurred in the west caisson had we not kept the center of gravity down. Even when 20 feet into the bottom, the removal of one pocket of about 150 square feet area would give the caisson a list of a foot or more.

## DISAPPROVAL OF TYPE OF CAISSON

The writer wishes to go on record with a serious disapproval of the type of caisson used at Poughkeepsie, as compared with the old-time method of building caissons with air pockets. With the Poughkeepsie plan the work was always about the water level, hence no stability. After the concrete walls were built to —31 there was no way of adding any material weight to sink the caisson if great friction developed, as it did on the west caisson. Again, it was necessary to build, at very heavy expense, false bottoms to hold up the caissons until they were landed.

We spent over \$10,000 in removing the bottoms on the east caisson alone, aside from the tremendous expense of righting this caisson. Incidentally, the caisson could not have tipped over with the air pocket construction, under which plan the center of gravity would have been very low.

With air pockets, a comparatively light caisson side structure of timber above a steel cutting edge would not have had a draft exceeding 50 feet, which would require a light false bottom, and this could have been removed before landing the caisson. This would have required, possibly,

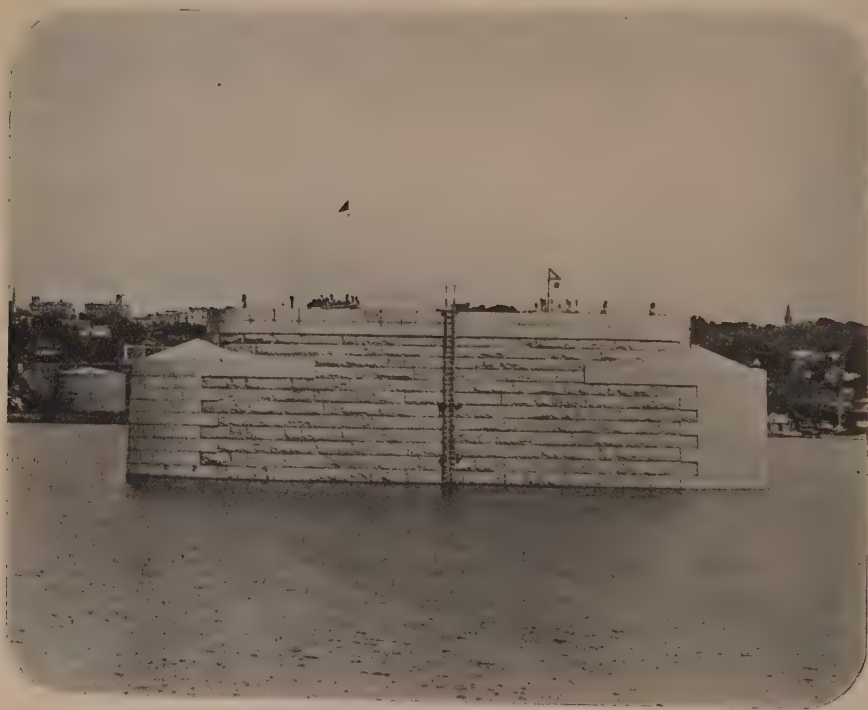


FIG. 15. — WEST PIER FINISHED

a 30-foot cofferdam. With this construction the concrete would all have been 25 feet or more below the water line, thus making the caisson absolutely stable under all conditions.

#### UPPER SECTIONS OF PIERS

The east caisson was sunk to grade December 8, 1928, and work began at once to fill the pockets to grade -31, which required 20,000

yards of concrete. By working a double shift 13,000 yards of concrete were placed in the upstream half of the caisson up to December 26, when the river began to freeze. Two or three days were required to clear out the laitance and silt in the downstream pockets which had not been filled, and the work finally was shut down on January 6, 1929.

On March 19 the work was resumed. The lower end pockets were cleaned out and the concrete finished to grade -31 on March 26, placing 7,000 yards with a submarine bucket. The best record for twenty-four hours was 1,200 yards. The second lift of concrete from grade -31 to grade -7 required 3,600 yards, which was placed in twelve days. This operation necessitated the installation of a pumping plant; pumping the cofferdam, 135' x 60' down to elevation -32; cleaning out the small amount of laitance that had accumulated; draining isolated water pockets; placing of reinforcement; and the setting of some 6,000 square feet of forms.

The laying of the masonry of these piers was begun on April 18.

The placing of the 1,600 yards of stone masonry and the 3,600 yards of concrete backing was completed on May 16. A total of 14,200 cubic yards of concrete and 1,600 cubic yards of stone masonry had been placed in one month and twenty-seven days; all without any trouble or delay.

The piers were accepted by the State on June 15, 1929.

### QUANTITIES

The quantities of materials in these piers were as follows:

|                                                  |        |
|--------------------------------------------------|--------|
| Concrete (cubic yards)                           | 72,300 |
| Granite face masonry (cubic yards)               | 3,200  |
| Cement (barrels)                                 | 90,000 |
| Reinforcing steel (tons)                         | 700    |
| Structural steel (tons)                          | 500    |
| Steel in cutting-edge section of caissons (tons) | 1,100  |
| Timber in permanent work (M feet B. M.)          | 225    |
| Timber in temporary work (M feet B. M.)          | 1,200  |

This work was done by the Blakeslee Rollins Corporation of Boston, under the personal direction of J. W. Rollins, Vice-President, ably assisted by R. J. Reigeluth, of C. W. Blakeslee & Sons, Inc., of New Haven, Connecticut, whose close contact with and advice on the work was of greatest help. To our Superintendent, W. G. Cheever, great credit is due for his perseverance and ability and unfaltering courage in a most disheartening job.

### PERSONNEL

The contract was let by the State of New York, and the work done under the Superintendent of Public Works, Frederick Stuart Greene; Modjeski & Moran were the engineers in direct charge. The engineers representing the State were W. M. Acheson, J. S. Bixby and L. S. Hulburd; and the engineers on the site, representing Modjeski & Moran, were P. P. Angier and C. W. Hanson. We wish to acknowledge the great assistance given us by G. B. Woodruff, assistant engineer of Modjeski & Moran, in working out the details of construction.

### Discussion

QUESTION: I would like to ask Mr. Rollins whether with all his previous experience he did not foresee the possibility of that caisson's tipping over?

MR. ROLLINS: Apparently everybody connected with the work considered that when the caisson was 10 feet into the bottom of the river there was no danger of any considerable rotation. Our method of sinking the caissons was to excavate on one side to give the caisson a list of two or three feet, then reverse the operation and list it the other way, then taking the ends in a similar manner, and so "worrying" the caisson down.

The trouble in the east caisson was that after it had taken a slight list to the east, the 3,600 tons of concrete above the water level created an excessive moment of rotation, enough to overcome the resistance of the supporting bottom, so that the caisson tipped to 43 degrees.

Our men had never given any thought to the question of stability, although we provided for connections on the caissons in eight places, at three elevations, 21 feet, 53 feet and 80 feet above the cutting edge, if any side lines should be necessary to keep the caissons straight, or to create a pull to level them up.

With 500 tons of steel in the bottom section of 21 feet, it was evident that the caisson was stable while afloat, though the engineers directed us to put 200 tons of sand in the bottoms of the caissons, when they were drawing 50 feet. After these orders were given we relied on the engineers in our sinking operations, and gave no thought to the question of stability.

MR. HENRY F. BRYANT: May I ask Mr. Rollins what he would suggest we should do, in such a case, in the matter of design?

MR. ROLLINS: As I have stated, in my opinion the caisson was not well designed, being merely a shell, with no loading pockets, so that the concrete was always at the water line, giving no stability. Again, this shell was very heavy, 200 tons per foot in the concrete section, against 203 tons of weight of water displaced.

This great weight required very heavy false bottoms to withstand the estimated water pressure of 80 feet; and the soil conditions met with on the east pier made their removal a desperate task.

Again, as the flotation of the caisson brought the concrete top line practically to the water level, we had to rely on our wooden sides, 4 inches thick, on light angles, 16 feet between structural steel posts, to hold our very heavy floating plant. We found at once that these sides would not hold our plant, so we had to keep the outside concrete walls 4 to 6 feet above the other walls. This required extensive bulk-heading of concrete.

As against this design the old method of loading-pockets and air-pockets offers much cheaper and safer construction, would have required a much lighter false bottom, and would always have a great factor of safety as to stability, as the concrete in the filling pockets would have been 20 to 25 feet below the water level.

Again, these loading pockets would have provided more weight to sink the caissons, which our Poughkeepsie caissons did not have.

In sinking the west caisson it required a month to sink it 5 feet, although the excavation was below the cutting edges, because we could not add a ton more weight, all the concrete having been placed. The west caisson went to elevation -114.2, 57 feet into the bottom, requiring two months to sink it the first 15 feet. The east caisson went through coarse sand and was sunk to elevation -134.4, 77 feet into the bottom, 35 feet in forty-three days.

Nobody believed we could get the east caisson down to contract grade on account of the friction, but the sand ran to our buckets and the caisson sank without shaking by dynamite or by jetting.

John F. O'Rourke built the foundations for the railroad bridge at Poughkeepsie, about a mile above our bridge, fifty years ago, and he got them down without any trouble. We come along fifty years later, with our modern science, and the caisson tips over. So it looks as though we had not progressed much, particularly in the design of caissons.

# OF GENERAL INTEREST

## ARCHIMEDES

*By Edward Grossman*

One of the greatest scientists and engineers of all times was Archimedes of Syracuse, born there about 287 B.C. He was the son of Phedias, an astronomer, and was on intimate terms with, if not related to, Hiero, the King of Syracuse, and Gelo, his son. Like many a youth of the time he was sent to Alexandria to study, and doubtless met there Conon of Samos, whom he admired as a mathematician and cherished as a friend, and to whom he communicated his discoveries before publication.

On his return to Syracuse, where he spent the rest of his life, Archimedes devoted himself primarily to research in mathematics and mechanics, and secondarily to engineering. He set no value on the ingenious devices he invented, declining to have any written record of them except the "Sphere-Making," which explains the construction of a sphere he made to imitate the motion of the sun, the moon and the five planets. Archimedes contended that even his military engineering works, constructed for the defence of his native city from aggression by the Romans, were not worthy of notice; that only research in pure science was of value to mankind and therefore only its results were worthy of preservation.

That is why we find that although a majority of his works on mathematics

and mechanics are either extant or identified through other writers, his achievements in military engineering have been so interwoven with legend that he appears in that respect a legendary character, so utterly remarkable are his works.

Thus there is a story that when the Roman fleet invested Syracuse, Archimedes constructed a burning-mirror which set the ships on fire when they were within a bowshot of the wall. This has, however, been discredited, since it is not mentioned by Polybius, Livy or Plutarch.

Of his heavy artillery there is more authentic information. According to Plutarch's account of the siege of Syracuse by the Romans, the Syracusans were so beset both on land and on sea that they imagined it impossible for them to defend themselves against their numerous enemy. "But when Archimedes fell to handling his engines, and set them at liberty, there flew in the air infinite kinds of shot, and marvelous great stones, with an incredible noise and force on the sudden, upon the footmen that came to assault the city by land, bearing down and tearing in pieces all those which came against them or in what place soever they lighted, no earthly body being able to resist the violence of so heavy a weight; so that all their ranks were marvelously

disordered. And as for the galleys that gave assault by sea, some were sunk with long pieces of timber like unto the yards of ships, whereto they fasten their sails, which were suddenly blown over the walls with the force of their engines into their galleys, and so sunk them by their over great weight."

Thus we see that Archimedes not only was expert in the use of levers and springs, since his projectile-throwing machines were very likely ballistæ, — the motive power of which are springs which actuate the projectile-throwing levers, — but that he appreciated the value of a lengthy projectile as a destructive agent, and thus anticipated the chain-shot and bar-shot of the eighteenth and nineteenth centuries, and the more modern projectiles known as shells, the only difference being that Archimedes' shells depended on their weight to cause the damage, while modern shells depend on their explosive charges.

Archimedes was also great in mechanical engineering. He invented the water-screw, used for pumping water. This device consisted of an axle around which was wrapped an inclined plane, resembling somewhat a modern screw. This was fitted snugly into a cylindrical casing. Upon the intake end of the water-screw being immersed in the water to be lifted and the screw being rotated, the water actually moved up the inclined plane and discharged at the upper end.

Apparently he also invented the worm-and-gear, for, according to Sedgwick and Tyler,\* "On occasion of difficulty in launching of a certain ship he successfully applied a cogwheel apparatus with an endless screw."

A saying attributed to Archimedes is, "Give me a place to stand and I move the earth," said to have been made when he demonstrated the lever to

Hiero. Any given weight, he stated, could be moved, given the force. "Hiero being struck with amazement at this, and entreating him to make good this problem by actual experiment, and show some great weight moved by a small engine, he fixed accordingly upon a ship of burden out of the king's arsenal, which could not be drawn out of the dock without great labor and many men; and, loading her with many passengers and a full freight, sitting himself the while far off, with no great endeavor, but only holding the head of the pulley in his hand and drawing the cords by degrees, he drew the ship in a straight line, as smoothly and evenly as if she had been in the sea." This quotation from Plutarch describes probably a sort of winch-and-pulley rig such as is sometimes used for pulling out tree stumps.

Archimedes' greatest fame, however, rests on his work in mathematics and mechanics. In mechanics he discovered what is now called Archimedes' Principle, that a floating body displaces its own weight of liquid. The discovery of this principle, according to Vitruvius, occurred thus:

"Though Archimedes discovered many curious matters that evinced great intelligence, that which I am about to mention is the most extraordinary. Hiero, when he obtained the regal power in Syracuse, having on the fortunate turn of his affairs decreed a votive crown of gold to be placed in a certain temple to the immortal gods, commanded it to be made of great value, and assigned for this purpose an appropriate weight of the metal to the manufacturer. The latter, in due time, presented the work to the king, beautifully wrought; and the weight appeared to correspond with that of the gold which had been assigned to it.

"But a report having been circulated

\* A Short History of Science, p. 106.

that some of the gold had been abstracted and the deficiency thus caused had been supplied by silver, Hiero was indignant at the fraud, and unacquainted with the method by which the theft might be detected, requested Archimedes to give it his attention. Charged with the commission, he by chance went to a bath, and on jumping into the tub perceived that, just in the proportion that his body became immersed, in the same proportion the water ran out of the vessel. Whence, catching at the method to be adopted for the solution of the proposition, he immediately followed it up, leapt out of the vessel in joy, and returning home naked, cried out with a loud voice that he had found that of which he was in search."

His mathematical proofs in mechanics were the first ever made.

In mathematics he made great progress in algebra, increased the knowledge of geometry, and in some of his work anticipated even the calculus. His greatest work was in geometry.

Of his published works the following are extant:

- (a) On the Sphere and the Cylinder.
- (b) The Measurement of the Circle.
- (c) On Conoids and Spheroids.
- (d) On Spirals.
- (e) On the Equilibrium of Planes (or centers of gravity of planes).
- (f) On the Quadrature of the Parabola.
- (g) Of Floating Bodies.
- (h) The Psammites, a small treatise expounding (as applied to reckoning the number of grains of sand that could be contained in a sphere the size of our universe) a system of naming large numbers according to orders and periods which would enable any number to be expressed up to that which we should write by 1 followed by 80,000 ciphers, or expressed in the usual notation,  $1 \times 10^{80000}$ .

- (i) A collection of Lemmas, consisting of 15 propositions in plane geometry.

Of his lost works we can identify the following:

- (a) Investigations in Polyedra.
- (b) Principles, dealing with the naming of numbers on the system noted in the description of The Psammites.
- (c) Balance, or Levers.
- (d) Centers of Gravity.
- (e) An optical work of which Theon of Alexandria quotes a remark on refraction.
- (f) Sphere-making (noted above).

Archimedes was killed in 212 B.C., at the fall of Syracuse. Marcellus, the Roman commander, greatly regretted the death of the sage. To quote from Plutarch once more:

"Nothing afflicted Marcellus so much as the death of Archimedes, who was then, as fate would have it, intent upon working out some problem by a diagram, and having fixed his mind and his eyes alike on the subject of his speculation, he never noticed the incursion of the Romans, nor that the city was taken. In this transport of study and contemplation, a soldier, unexpectedly coming up to him, commanded him to follow to Marcellus, which he declined to do before he had worked out his problem to a demonstration; the soldier, enraged, drew his sword and ran him through."

While Archimedes' work as an engineer was, so to speak, a sideline with him, there is no denying the fact that he consciously used the principles of mechanics and mathematics to solve problems in engineering in the same manner as does the present-day engineer.

## PROCEEDINGS OF THE SOCIETY

### MINUTES OF MEETINGS

#### Boston Society of Civil Engineers

SEPTEMBER 25, 1929. — The regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall and was called to order by the President, Frank E. Winsor, at 7.15 P.M. There were 150 members and guests present.

The minutes of the previous meeting (May 15, 1929) were approved as published in the June JOURNAL.

The Secretary reported that the Board of Government had elected the following to membership:

*Grade of Member:* Francis Ring Morgan.

*Grade of Junior:* Russell Cushing Chase.

The President reported that the Board of Government had voted to omit the regular meeting in October in order that members may attend the technical sessions of the fall meetings of the American Society of Civil Engineers, to be held on October 9 and 10 in Boston.

The President reported the death of Henry Fletcher Bryant on June 16, 1929, who had been a member since December 19, 1888. He stated that a committee would be appointed to prepare a memoir.

The President then presented the speaker of the evening, J. F. Bagley, Jr., of Fairchild Aerial Surveys, Inc., who gave a talk on "The Economic Application of Aerial Surveys." Following the presentation of this paper, several phases of the use, adaptability and value of this method of obtaining information for maps and other purposes were discussed by the following: Prof. Charles M. Spofford, M. I. T.; Mr. Frederick N. Fowler, Engineer; Mr. Karl R. Kennison, Designing

Engineer, and Mr. N. Leroy Hammond, Division Engineer, of the Metropolitan District Water Supply Commission, and others.

Meeting adjourned at 9.30 P.M.

EVERETT N. HUTCHINS, *Secretary*.

#### Northeastern University Section

OCTOBER 3, 1929. — The first seasonal meeting of the Northeastern Section of the Boston Society of Civil Engineers was held Thursday, October 3, in Room 26H of Huntington Hall. The student engineers present were greeted by Chairman Fred E. Hess, who outlined briefly the purpose of the Section.

The speaker of the evening, Mr. William W. Lewis, Assistant Engineer of the Boston Transit Department, in charge of the Dorchester Rapid Transit Project, used as his subject, "Interesting Features of the Transit Development." He spoke in detail of the various phases of that undertaking, and from his personal experiences, which proved particularly interesting, covering eleven years since his first connection with this movement when it started. Detailed drawings and blue prints were used to illustrate the progress of this work. The practical features of this project, both from an engineering and business standpoint, were presented.

In the discussion following the talk, questions regarding accuracy of survey work, triangulation of Boston Harbor, and future transit projects were answered by Mr. Lewis.

Thirty members attended the meeting. Refreshments were served at the close of the discussion.

The meeting adjourned at 10.15 P.M.

ERNEST S. HILL, *Clerk*.

## APPLICATIONS FOR MEMBERSHIP

[October 20, 1929]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

### *For Admission*

ANDERSON, CHARLES M., Somerville, Mass. (Age 21, b. Roxbury, Mass.) Is a student at Northeastern University. Refers to *H. B. Alvord, C. O. Baird, J. W. Ingalls, W. E. Nightingale*.

BRITT, JOHN HAVEN, Cambridge, Mass. (Age 20, b. Somerville, Mass.) Is a student at Northeastern University. Refers to *H. B. Alvord, C. O. Baird, J. W. Ingalls, W. E. Nightingale*.

CAVAZZANI, JOSEPH PAUL FRANK, Somerville, Mass. (Age 21, b. Bologna, Italy.) Is a student at Northeastern University. Refers to *H. B. Alvord, C. O. Baird, J. W. Ingalls, W. E. Nightingale*.

COHEN, HENRY, New Bedford, Mass. (Age 22, b. Boston, Mass.) Educated in East Boston High and New Bedford High. Is now a student at Northeastern University. Refers to *H. B. Alvord, C. O. Baird, J. W. Ingalls, W. E. Nightingale*.

GIURANOVICH, Jr., ARTHUR JOSEPH, Boston, Mass. (Age 34, b. New Orleans, La.) Graduate of Massachusetts Insti-

tute of Technology, 1918, with degree of S.B. Experience: ship draftsman, Boston Navy Yard, 1920; structural draftsman, office of engineer of structures, Boston & Maine Railroad, 1921-22; 1922 to date, architectural and structural engineering with various firms. Refers to *L. M. Hersum, F. H. Morris, J. H. O'Connor*.

HAVEN, MARTIN ROCKWOOD, Worcester, Mass. (Age 22, b. Worcester, Mass.) Graduated from Middleborough High School in 1926, and in the fall of that year entered Northeastern University. During co-operative periods has worked for George Clements of Hyannis, as rodman and transitman; also for the town of Framingham as rodman, transitman and chief of party. Refers to *H. B. Alvord, H. L. Burton, F. E. Hess, E. S. Hill, J. W. Ingalls*.

HERSEY, HAROLD GEORGE, Wolfeboro, N. H. (Age 22, b. Wolfeboro, N. H.) Entered Northeastern University in the fall of 1927. During co-operative periods has worked with the late Henry F. Bryant, Connecticut River Development Company, H. B. Reed & Son, Woodsville, N. H., and Goodwin & Doe, Wolfeboro, N. H. Refers to *W. J. Alcott, Jr., H. B. Alvord, G. B. Gee, J. W. Ingalls, W. E. Nightingale*.

HOLMSTROM, TOIVO ALBERT, Vinalhaven, Me. (Age 21, b. Vinalhaven, Me.) Graduated from Vinalhaven High School in 1926 and entered Northeastern University. During co-operative periods has worked for Ernest W. Branch as rodman; for Barnes & Beal of Waltham, and is at present transitman for this firm. Refers to *H. B. Alvord, C. O. Baird, J. W. Ingalls, W. E. Nightingale*.

KILPATRICK, LAWRENCE EDWARD, West Newton, Mass. (Age 23, b. Brooklyn, Conn.) Graduate of Killingly High School in 1923 and now a senior at Northeastern University. During the co-operative periods has worked for the city of Newton as rodman, instrumentman, and at times acting as chief of party; has also worked as rodman for Gilbert Perry of Putnam, and as tracer in the office of Charles Gowen, Boston. Refers to *H. B. Alvord, C. O. Baird, J. W. Ingalls, W. P. Morse, A. Q. Robinson*.

LEAHY, JAMES JOSEPH, Somerville, Mass. (Age 23, b. Somerville, Mass.) Is a student at Northeastern University. Refers to *H. B. Alword, C. O. Baird, J. W. Ingalls, W. E. Nightingale.*

LYMBERG, JOHN WILLIAM, Boston, Mass. (Age 20, b. Gardner, Mass.) Graduate of Gardner High School in 1927 and entered Northeastern University that fall. During the co-operative periods has worked for Everett M. Brooks, C.E., at Newtonville, and at present is working for Whitman & Howard. Refers to *H. B. Alword, C. O. Baird, Oral Calderara, J. W. Ingalls, K. D. Sylvester.*

RICHARDSON, COBURN M., Boston, Mass. (Age 20, b. Mars Hill, Me.) Graduate of Groveland High School in 1924 and entered Northeastern University in September, 1927. During co-operative periods has been employed by Morton C. Tuttle Company, and Turners Falls Power Company at Cobble Mountain Reservoir, Westfield; also by Mr. Freeman of Hartford, Conn. Refers to *H. B. Alword, C. O. Baird, J. W. Ingalls, K. D. Sylvester, C. A. White.*

SCHAIER, ARNOLD EDWIN, Norwood, Mass. (Age 21, b. Norwood, Mass.) Graduate of Norwood High School in class of 1926 and entered Northeastern University. During co-operative periods has worked as transitman for W. N. Chittenden of Braintree, and G. H. Wetherbee. Refers to *W. J. Alcott, Jr., H. B. Alword, C. O. Baird, E. S. Hill, J. W. Ingalls.*

SHERIDAN, BERNARD BRINSLEY, Boston, Mass. (Age 23, b. Winnipeg, Can.) Is a student at Northeastern University, and during co-operative periods has worked for the Aberthaw Company, on a job in New York State, R. L. Hayward, C.E., and landscape engineer, of Taunton, Mass. Refers to *H. B. Alword, C. O. Baird, G. A. Gee, J. W. Ingalls.*

SMITH, JOSEPH AUBREY, Everett, Mass. (Age 21, b. Everett, Mass.) Graduate of Everett High School in 1926. Now a student at Northeastern University. During co-operative periods has been employed by John Rand of Melrose as transitman; by Charles Gannett of Arlington for a short time before his death; now employed by Newell B. Snow, County Engi-

neer of Barnstable County, as chief of party. Refers to *W. J. Alcott, Jr., H. B. Alword, C. O. Baird, Jr., J. W. Ingalls.*

SYLVESTER, MERTON EUGENE, Boston, Mass. (Age 21, b. Westfield, Me.) Graduate of Groveland High School in 1926, and entered Northeastern University in 1927. During co-operative periods has been employed on bridge construction by Charles Reed of Yonkers, N. Y.; has also worked for Aspinwall & Lincoln for twenty-one weeks, and is now a transitman with them. Refers to *H. B. Alword, C. O. Baird, J. W. Ingalls, C. A. White, C. A. Wolfrum.*

TARR, VANCE SOUTHWELL, Somerville, Mass. (Age 21, b. Somerville, Mass.) Graduated from Somerville High School and is now a student at Northeastern University. During co-operative periods has been employed by Berry's Drafting Service, Mr. Maynard, City Engineer of Medford, Mass., Mr. Hartley L. White, Braintree, and the Boston Consolidated Gas Company. Refers to *H. B. Alword, C. O. Baird, Jr., J. W. Ingalls, W. E. Nightingale.*

VERNER, ROBERT HENRY, Boston, Mass. (Age 22, b. Erving, Mass.) Graduate of Turners Falls High School and now a student at Northeastern University. During co-operative periods has been employed in the engineering department of the Springfield Gas Light Company as draftsman, rodman and transitman. Refers to *H. B. Alword, C. O. Baird, J. W. Ingalls, V. L. Stone, K. D. Sylvester.*

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## DEATHS

HENRY FLETCHER BRYANT, died June 16, 1929.  
WILLIAM F. WILLIAMS, died October 1, 1929.



## BOSTON SOCIETY OF CIVIL ENGINEERS

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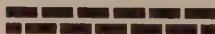
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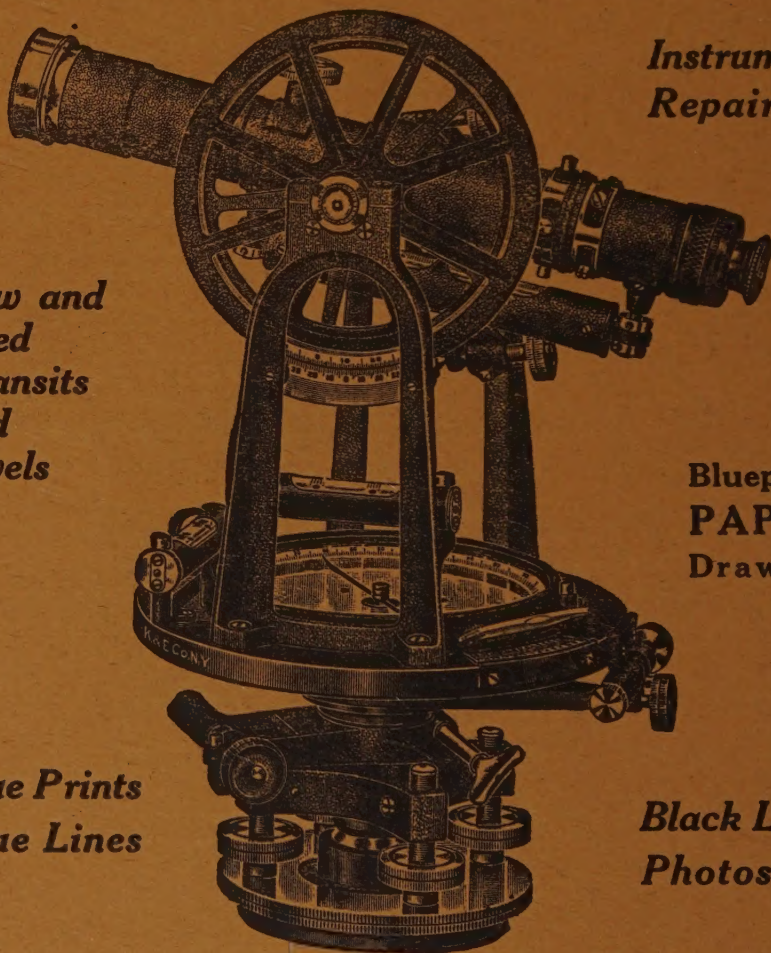
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